Using LEGO RCX Bricks as the Platform for Interdisciplinary Design Projects

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Abstract

The activity of real world design is a collaboration of individuals from more that one discipline. To address this issue, a student interdisciplinary design project was created. For the past four years, teams of students from the freshman Engineering Design Graphics course and the sophomore Industrial Design Studio were formed. In previous years, push-pull toys were designed and constructed. For the past two spring semesters, the new LEGO Programmable RCX bricks were chosen as a medium for the interdisciplinary design project. Each team of students was charged with designing and programming an autonomous guide vehicle (using the LEGO RCX bricks and Robolab software) that would travel a minimum of 15 feet and accomplish some designated action. The site that the vehicle would traverse was also to be designed, as well as a "postscript" or added device, not to be made of LEGO that would attach to the guide vehicle and add to the mission of the autonomous vehicle. The paper first describes in detail the brief of the project given to the students. Subsequently, the paper records the process of design and path of production of the project. The diverse vehicles and sites are documented. Further, there is a discussion of the contributions of both the industrial design and engineering students – how teams defined their work ethic and division of labor. Finally the assessment process of the project is discussed. This paper serves as a visual record of an exciting and creative foundation design effort.

Introduction

In the spring of 1997, we had a notion that a collaboration of engineering and industrial design students would bring about a new and exciting possibility for our students to experience the activity of real world design in their foundation years at the university.

The first year, we established teams of two students - one engineering student and one industrial design student. The project was called STILLS. In this project, the students were charged with designing a mobile or push-pull toy that satisfied certain criteria. There were 28 teams and about half the teams designed mobiles and half the teams designed push-pull toys. Most of the teams designed very innovative and interesting projects. AutoCAD drawings were made of each project, the industrial design students created posters, the engineers produced written reports, and the team delivered a final oral presentation. The complete details and results of this project were reported at the 1997 EDGD Mid-year meeting in Madison, WI [1]. One outcome we discovered was that the volume of projects limited our ability to coach each team. Also, weaker teams did not have resources (additional members) to support them through hard times.

The following spring, we formed teams of four students each. Two engineering students and two industrial design students made up each team. The charge this year was to design a push-pull toy that would satisfy more rigorous criteria than was used the year before. The results of the larger team size and consequently smaller number of teams were mixed. Having fewer teams seemed to produce less fanciful toys. Larger team sizes meant that there were more internal resources available. We were also able to spend more coaching time with each team.

Spring of 1999, we formed eight teams of seven or six students each. Each team consisted of three engineers and four or three industrial designers. This team composition created a more resourceful group. It also resulted in a couple of teams having increased conflict among team members. To achieve a better team size, spring of 2000 we formed 12 teams of four students each. LEGO programmable RCX bricks were chosen as the medium for this interdisciplinary design project. Each team of students was charged with designing and programming an autonomous guide vehicle (using the LEGO RCX bricks and Robolab software). The guide vehicle was required to travel a minimum of 15 feet and accomplish some designated action. The students also designed the site that the vehicle would traverse, as well as a “postscript” or added device, not to be made of LEGO that would attach to the guide vehicle and add to the mission of the autonomous guide vehicle. The resulting guide vehicles, sites, and postscripts varied greatly in their design concept, function, and mission. One vehicle moved along a horizontal wire and dispensed and sorted balls, another sought out colored dots in a particular sequence and when all were found unfolded like a flower, and a third launched a parachute and subsequently performed a search and rescue. There were a total of eight designs. The LEGO RCX was an excellent choice as the platform for this design project. The common hardware of LEGO and the Labview based Robolab software gave a unified foundation as well as allowing the space for individual creativity.

In another paper we delivered to the Industrial Designers Society of America on this work [2], the concept of mobility was discussed. This project further enriches this concept. Mobility suggests a relationship between elements–something moving with respect to something else. This relationship in turn can introduce mediation between materials or illuminate where mediation might occur. In essence, mobility compels one to look at the joint between dynamic and static elements and the junction of different materials. In this case, it was the junction between the LEGO world and the world of "ordinary" materials. How does one design an elegant transition - a synergy?

The LEGO RCX brick and other LEGO pieces provide a framework. Elegance might be found most immediately where one material or one element meets another–the union between different volumes, planes, materials, and conditions. The LEGO world is a framework within which students can develop sensibilities about the juxtaposition of form and materials.

As a conduit for the discussion of mobility, this paper presents a student project, "legoPOSTSCRIPT", involving teams of students from industrial design and engineering. The teams of seven or six students were formed, three or four from industrial design and three from engineering. Each team then chose the makeup of their team structure. The paper first describes the brief of the project given to the students. Subsequently, the paper records the process of design and path of production of the varied resulting products. Further, there is a discussion of the contributions of both industrial design and engineering students–how the teams defined their individual roles in the design process.

The paper serves as a visual record of a dimmed boundary between industrial design and engineering students. It also serves to illuminate the possibility of a union between LEGO and "ordinary" materials in unified design efforts.

Narrative

Alexander Calder described his mobiles as "abstractions which resemble nothing in life except their manner of reacting" [3] as Marcel Duchamp is credited with naming these works of Calder as "mobiles," it may be important to remember that, in French, the word also means motive. *Mobility* suggests a relationship between elements–something moving with respect to something else or because of something else. This relationship in turn can introduce mediation between materials or illuminate where mediation might occur. In essence, mobility compels one to look at the joint between dynamic and static elements and the junction of different materials. At this fundamental level, one might look at mobility as part of a platform serving as a foundation for design education.

As industrial design is gaining prominence at Virginia Tech, and when the university is strongly focused on bridging academic areas, it seems an opportune time to consider the blend of areas of thought which might compose a foundation in industrial design for both designers and engineers. What is at the core? We looked at Stanford University as a model for blend engineering and art as a base for product design and then noticed Virginia Tech's traditional separation of the two. We welcomed the opportunity to provide a meeting for engineering and industrial design students. Our broader goal was to have students from both worlds look at something together and then through each other's lens–to add not only their particular view of the world but also their view which now changes as a result of this new relationship.

What might be at the common core of such an association? Materiality certainly stands as common to these fields of study. How materials come together, how those decisions are made, becomes the substance of dialogue between industrial designers and engineers–the joint and materiality.

As teachers, we came together seeing a possibility of illumination in the way students view their work as designers. That possibility is modeled in the work of Alexander Calder. His work is an expression of a blended view, where the boundary between the pragmatics of movement and the form of movement dissolve in the process of making. Clearly, he makes this melding appear seamless and effortless. However, the relationship or hierarchy between form and function is probably the base issue of division between the fields of engineering and industrial design. We thought that looking at Calder's work as a precedent for understanding movement might serve as a starting point for dialogue between these two groups of students. Calder's training from the Stevens Institute of Technology and his early work as an engineer serve as a balance and compliment to his eventual development as an artist of mobiles [4, 5].

Perhaps it is better to talk about the lightness and lyric of movement before talking about pragmatics in order for students to *imagine* the possibilities of form. The objective here is to have industrial design and engineering students see the possibility of art in movement in order that art might always be an aspiration in the form of all design endeavors. We also strive here to have the students discover that some intangibles such as poetry–dance–in movement are indispensable rather than extravagant, and that poetry, too, can be efficient.

How and in what form does a teacher bring this perspective to a student? Perhaps the answer originates in the examination of current engineering and industrial design education. The education of first and second year engineering students at Virginia Tech is primarily analytically based. Engineering students are also isolated from other related disciplines on campus. As strong believers in broad-based education as the best preparation for a creative and productive life and career, we aspire to involve the engineering students in the physical design world at an early stage in the educational process. We felt that engineering students could nurture in parallel practical and aesthetic sensibilities from direct collaborative contact with industrial design students.

A hands-on, physical design project in their freshman year would broaden their experience and give them an appreciation for the discipline of industrial design.

Industrial design students in many schools have little immediate connection to engineering. Once they reach beyond preliminary ideas and refinement, industrial design projects are often intuitively analyzed. The introduction of engineering analysis and testing to support intuitive thinking adds tangible dimension to the design process. The blending of intuition with analytical thinking–designer with engineer results in the design being more comprehensive and compositional and the designers being more whole.

The activity of real world design is a collaboration of individuals from more than one academic discipline. In response to this reality, we have introduced a collaborative design project to two previously unrelated courses: a second semester freshman engineering course and a second semester sophomore industrial design studio.

The Project

The projects were to be collaborative designs of mobility deliverables using LEGO RCX bricks as the platform for design. The project brief delivered to the students at the introduction of the project is given in its entirety in the Appendix.

Selected Projects

The Lego RCX Challenge

As a way to generate some immediate familiarity with the LEGO RCX bricks, we set up a contest called the "LEGO RCX Challenge". In the challenge, teams of four students designed an autonomous vehicle that would be capable of negotiating a course twelve feet square with obstacles placed randomly in the space. To win the challenge, a vehicle needed to negotiate the course and run over an 8-inch by 10-inch target of black paper within five minutes. The teams could design either a wheeled vehicle or a tracked/treaded vehicle. Since laboratory time was restricted to two hours, the RCX bricks were pre-programmed with four robotic programs. A five-minute time limit wheeled vehicle, a reduced time limit wheeled vehicle, a five-minute time limit tracked/treaded vehicle, and a reduced time limit tracked/treaded vehicle. Reduced times were used if vehicles failed during the test and needed repairs. The vehicles had three inputs (two touch sensors and one optical sensor) and two outputs (two motors). Most vehicles were successful and all students got an excellent quick immersion into the world of Lego Robotics. The students were now ready to move on to the more demanding design of the legoPOSTSCRIPT project.

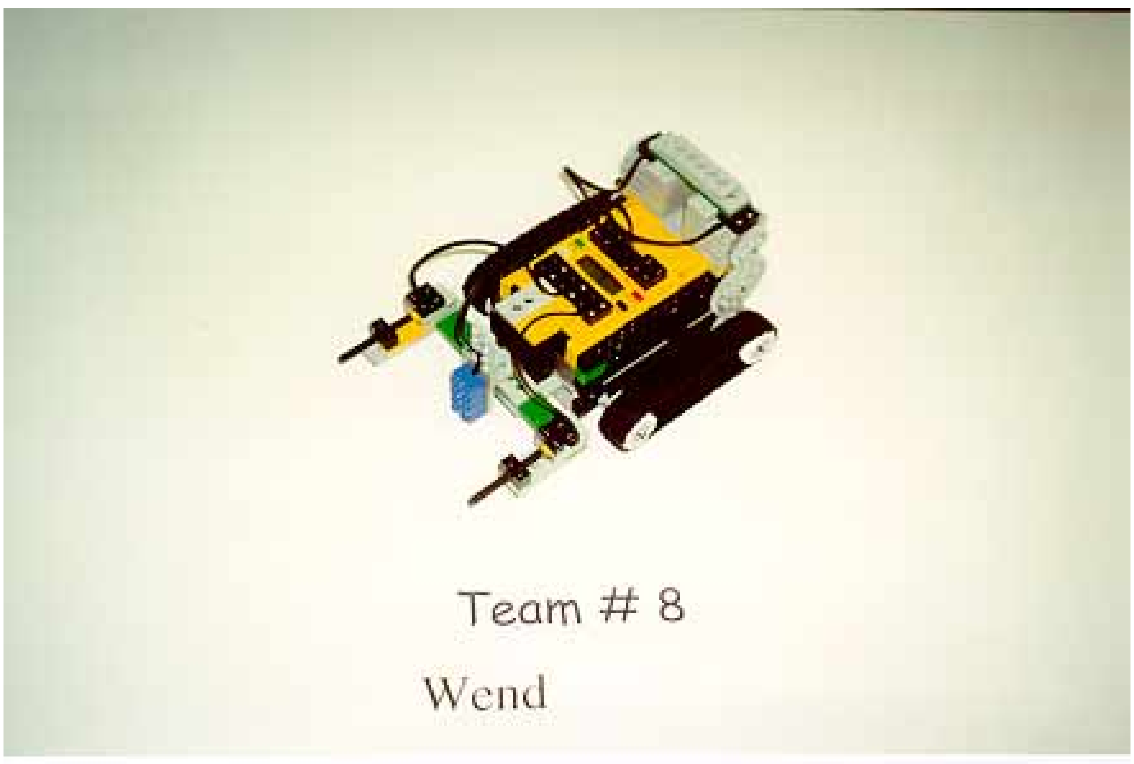

Figure 1. Lego RCX Autonomous Vehicle

Figure 2. Lego RCX Challenge Site

For the interdisciplinary design legoPOSTSCRIPT project, Robolab software was chosen as it operates on both IBM (engineers') and Mac (designers') computers. As was described in the design brief, each project consisted of a guide vehicle, site, and postscript. The guide vehicles for each project were programmed using Robolab computer programs that each team created on their personal computers. The programs were downloaded via infrared interface to the Lego RCX bricks. The guide vehicles then executed their missions autonomously. The following are descriptions of some of the more successful projects:

Ball Dispenser

The ball dispenser design was quite inventive. Here the guide vehicle moved along two wires suspended between the ends of a curved metal plate. The metal plate was shaped like a "U" semicircle and had a hole in the center at the lowest point of the curve. When the guide vehicle moved along the wires strung across the top, it eventually hit the metal sides. This caused a ball to be dispensed from the attached "postscript" ball hopper. The ball would slide down the metal sheet, oscillate a few times and then drop into the hole and into an empty hopper. Once all the balls were dispensed the device would stop and the ball hoppers could be exchanged and the process started again.

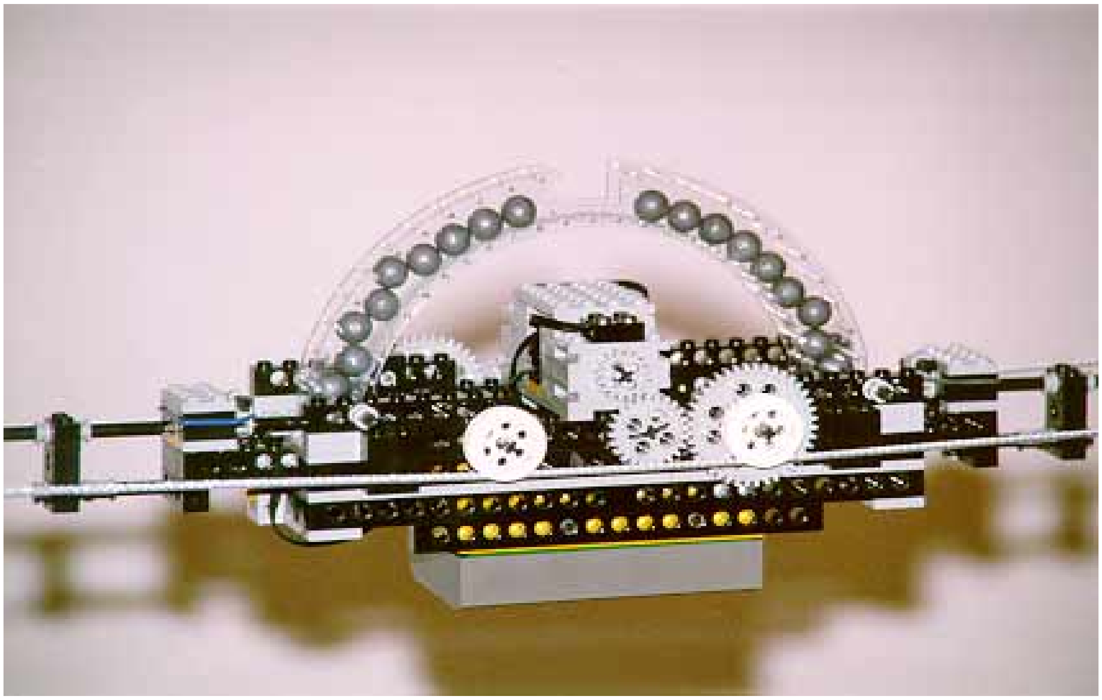

Figure 3. Ball dispenser

Figure 4. Metal Site with center hole

Tower and Train

This project design is notable because it included several different sequential actions. The guide vehicle followed a black course by means of optical sensing. As the vehicle moved along the course, a small figure was manually released from a tower, slid down a wire and dropped into a chute. The figure was subsequently released into a container sitting in the trailer (postscript) that was being towed behind the guide vehicle as the trailer came under the chute. Farther down the course, the container holding the figure was ejected from the trailer, through the use of imbedded magnets in the roadway.

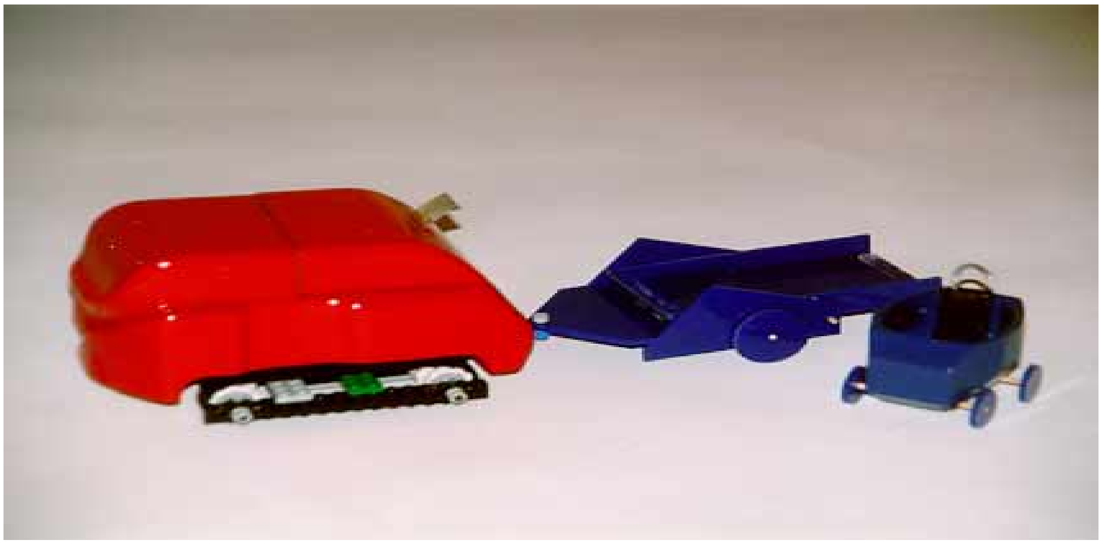

Figure 5. Train Guide Vehicle

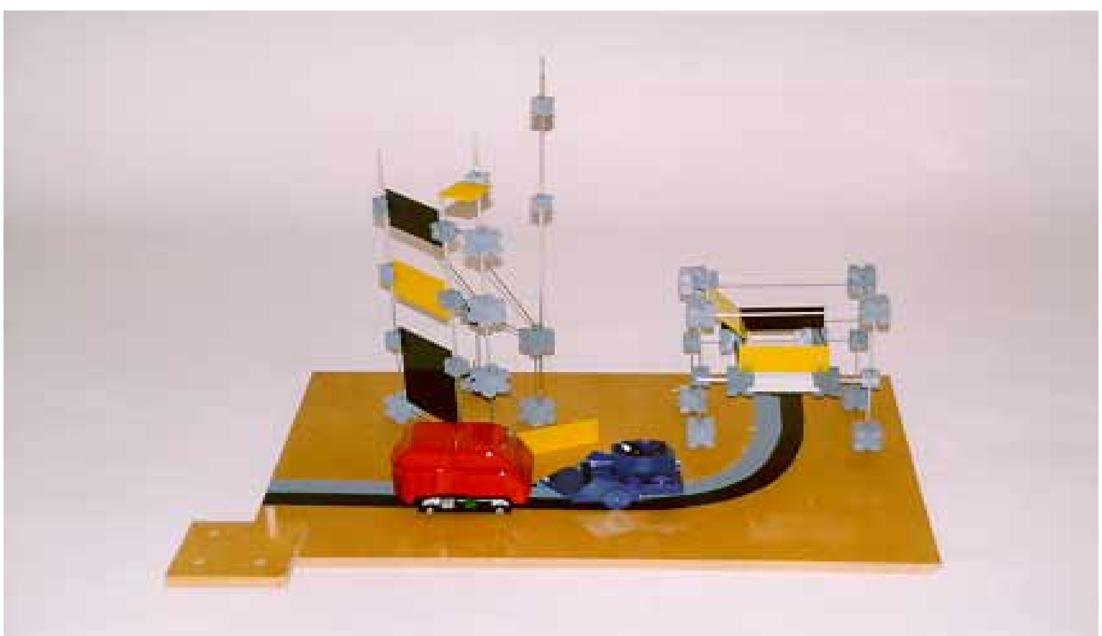

Figure 6. Site with tower, hopper and course

Flowering Pyramid

This was probably one of the most creative and elegant solutions. The guide vehicle and attached postscript resembled a moving pyramid. The site consisted of a defined area with several different colored circular disks placed on the surface. The vehicle, when set in motion, would search for the different colors by use of an optical sensor and remain inside the defined area by sensing the black perimeter of the space. The vehicle was programmed to discover the colored disks in a particular sequence. If the vehicle ran over a red disk, but was looking next for a green one, it just kept searching until the green one was encountered. After all disks were discovered in sequence, the pyramid stopped, an internal light came on causing the pyramid to glow (the pyramid sides were translucent). The triangular sides of the pyramid then folded back like the petals of a flower exposing the guide vehicle. It was quite a sight to behold.

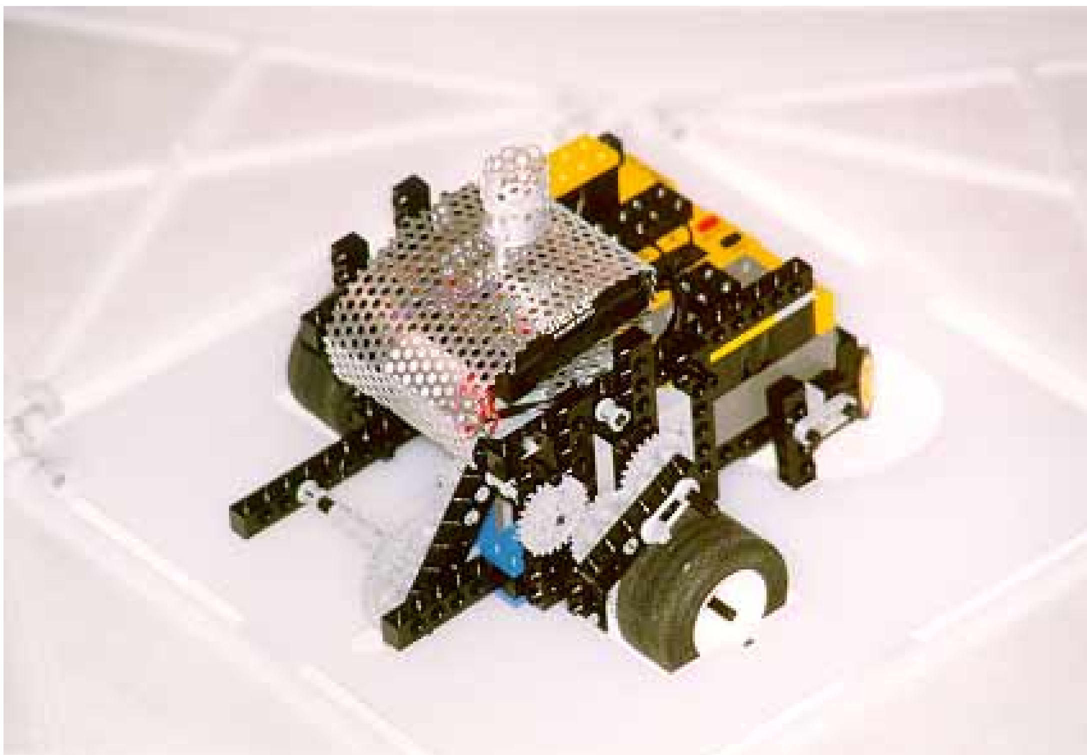

Figure 7. Pyramid vehicle close up

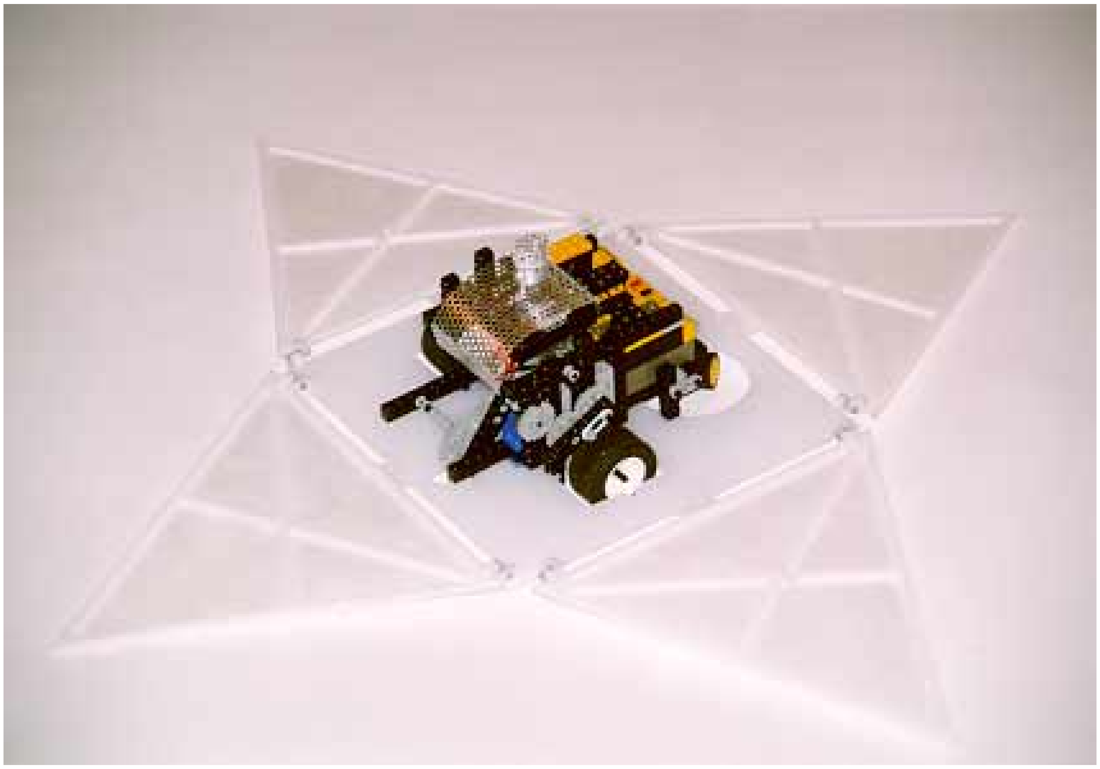

Figure 8. Pyramid vehicle open petals

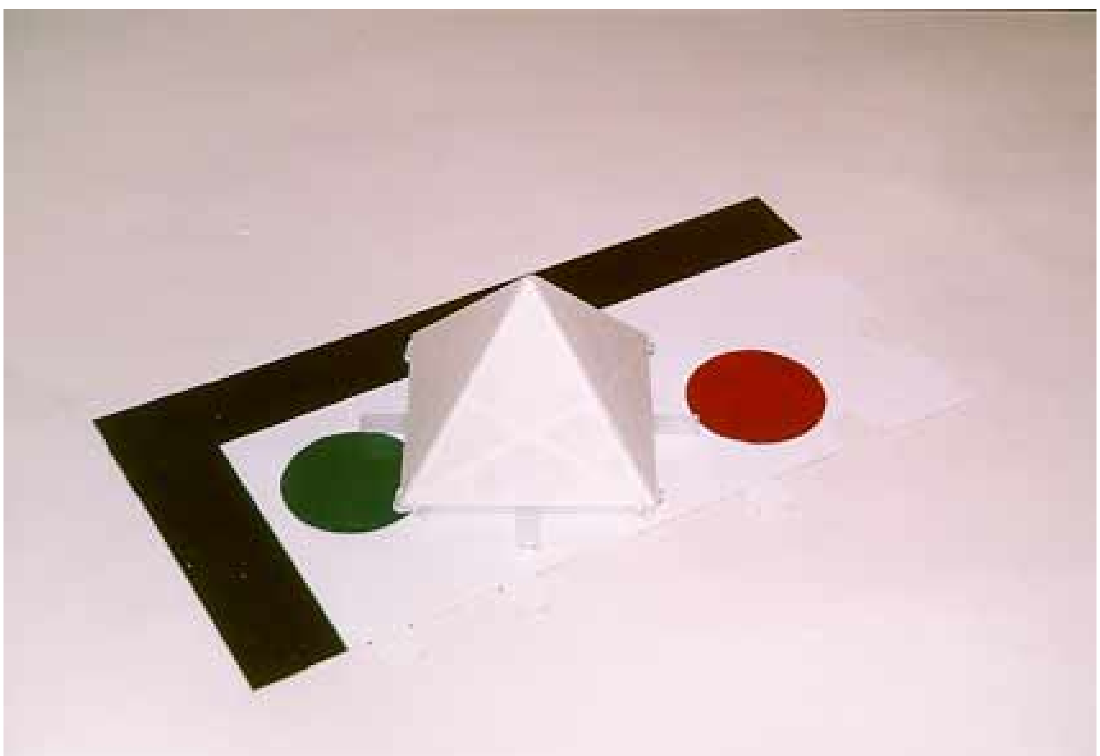

Figure 9. Site with colored dots and closed vehicle

Painting Vehicle

One of the most mechanically complex designs involved a vehicle that would move around a fixed area and play mechanical chimes. As it moved, it also painted random brush strokes on the canvas underneath. The complexity came in the design of the vehicle cover and support structure as well as the design of the integrated paint dispensers. The design of the internal chimes was simple and elegant.

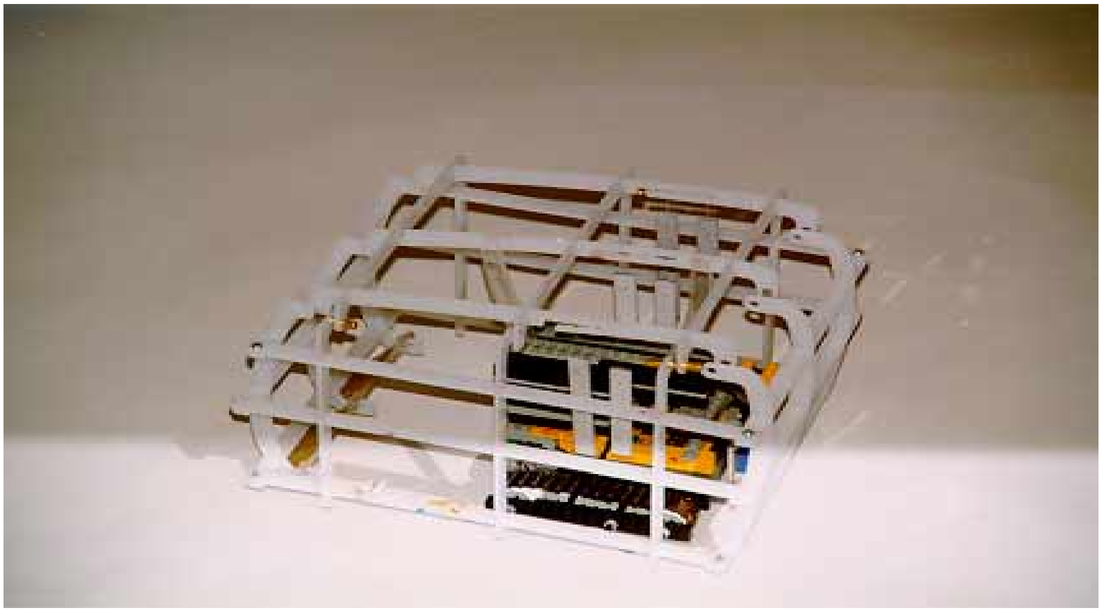

Figure 10. Painting vehicle without cover

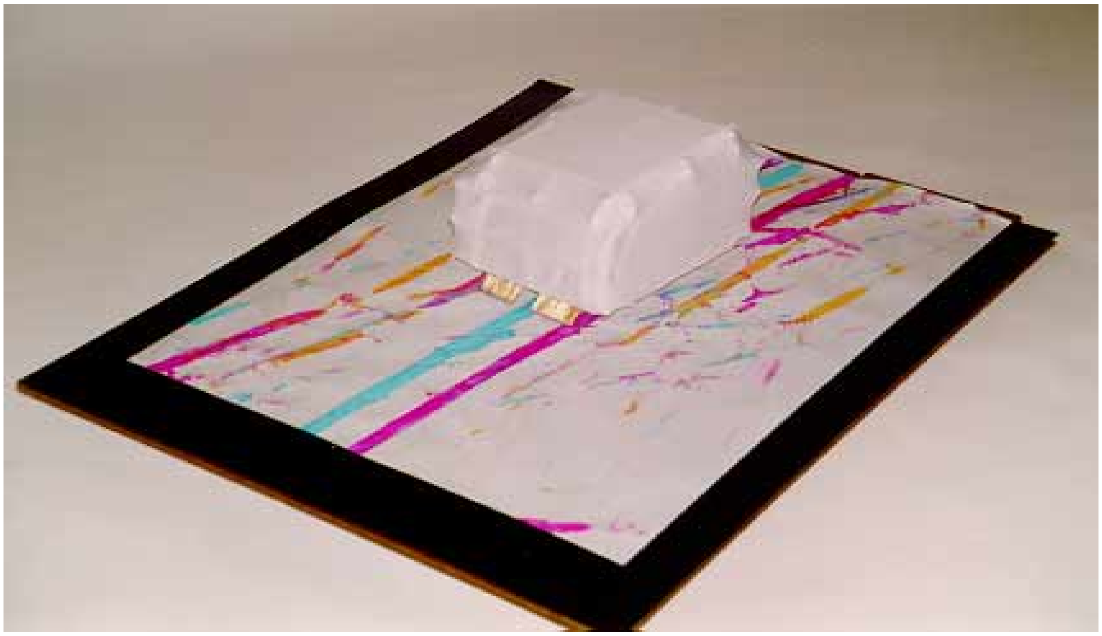

Figure 11. Painting vehicle with cover and on site

Conclusions and Assessment

This collaborative effort between Engineering Fundamentals and Industrial Design is a continuing project. We have received previous grant funding from the Center for Excellence in Undergraduate Teaching (CEUT) at Virginia Tech. The grant was awarded for development of an annual joint endeavor between engineering design graphics and the sophomore design studio. The recent completion and dedication of the Frith Freshman Engineering Design Laboratory and accompanying donations from industry have provided new resources to expand this interdisciplinary design concept in the future.

The discussion and results shown in this paper are from the third run of this seven-week project. As we began this experiment, we thought that we were looking for an understanding of elegance in the students' work, and indeed we found this in a significant portion of the projects, but we also discovered a profound elegance in their partnerships. We continue to search for means of evaluation of the project. We began this process four years ago with a series of questions for the students. The first set was an anonymous questionnaire, which asked the students if the project affirmed or altered their view of their own discipline or their partner's discipline. The majority of the responses indicated an increased understanding and appreciation for their partner's discipline and an affirmation of their own. From one engineering student: "There is more to engineering than taking in information and spitting out solutions. There is a creativity and freedom in design." From one industrial design student: "This project has grounded my romantic view of industrial design. Now, I have experience that supports the idea that communication between professions is very important." In the current team grouping we found that most of the teams worked well together. In two of the teams that did have significant conflicts, the conflicts were between two members of the same discipline. Also, the lack of strong work ethic (getting the job done) on the part of a few students did create isolated friction. There was never a sense of designers versus engineers. The large teams seemed generally to work well. We will probably continue working with teams of four to seven members.

The assessment of the projects are based on the elegance of the design, whether the design achieved the team's stated goals, did it work at the final demonstration, teamwork and team interaction, and the final portfolio. The final demonstration of these projects has become a well-attended event that faculty and students eagerly await at the end of spring semester. We hope that the success of the project presented in this paper will serve as a model for other diverse disciplines seeking more interaction.

Bibliography

[1] Goff, R.M. and Vernon, M.R., "Design – Blurring the Boundaries of Interdisciplinary Education", Proceedings of the ASEE 52nd Engineering Design and Graphics Division Mid-Year Conference, Madison, WI, October 25-26, 1997
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[3] Marter, Joan. Alexander Calder. Cambridge: Cambridge University Press, 1991.
[4] Calder, Alexander. An Autobiography with Pictures. New York: Pantheon Books, 1966.
[5] Lipman, Jean. Calder's Universe. Philadelphia: Running Press Book Publishers, 1976.

Appendix

LegoPOSTSCRIPT

This marks the third year of an industrial design / engineering student collaboration. This year the project brief includes a component: the Lego Robotics Invention System. Using one of the systems, you are asked to utilize the given materials to develop a guiding vehicle, a path/site for its travel, and finally (NOT using Lego materials), what we are calling a "postscript". This feature could be a trailer that accompanies the vehicle, or a tower that attaches to the vehicle or any other concept that is mobilized by the vehicle. The requirements for the postscript are the following:

It must be made from materials other than Lego except for necessary use of sensors or motors.

It must attach elegantly to the guiding vehicle.

The vehicle and postscript must travel a distance of at least 15 feet in the course of its journey.

It must REACT at some moment during the journey. Something in the path must cause a mechanical action in the postscript. For example, a left turn might always cause a flag to go up.

There will be 8 teams of 7 or 6 members. Each team will be comprised of 3 integrated Project Teams. We recommend the following structure, but will leave the ultimate allocations to you:

Software Team: 2 engineers
Site and Guide Vehicle Team: 1 industrial designer, 1 engineer
Postscript Team: 2 industrial designers
Project Manager: 1 engineer OR industrial designer

The Project Manager's responsibility will be to coordinate the activities of each group. It is critical that the group appoints and respects the responsibilities of the Manager. The manager will also decide which Project Team s/he wants to work with. Each team will need to purchase batteries (6 AA and 1 9-volt).

Schedule:

F, March 19:	Project Brief Delivered, Teams Chosen, and Lego Systems Distributed.
March 24-31:	Faculty meetings with teams.
F, April 2:	Concepts Presented. Drawings and Mock-ups of Guide Vehicle, Postscript, and Site (Should be presented for easy viewing).
April 5-16:	Faculty meetings with teams.
F, April 23:	Rough Prototypes Presented: Postscript, Guide Vehicle and Site.
April 26-30:	Faculty meetings with teams.
W, May 5:	Final Demonstrations Portfolios Due: (Bound Book: Annotation of Computer Programs, Drawings of Site and Description + image of Guide Vehicle, Conceptual and CAD Drawings + Image of Postscript).
Th, May 6:	Photography Opportunity. All vehicles and postscripts must be present with or without teams.

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